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PRECIPITABLE WATER VARIABILITY USING SSM/I AND GOES VAS PATHFINDER DATA SETS

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1. INTRODUCTION

Determining moisture variability for all weather scenes is critical to understanding the earth's hydrologic cycle and global climate changes. Remote sensing from geostationary satellites provides the necessary temporal and spatial resolutions necessary for global change studies. Due to antenna size constraints imposed with the use of microwave radiometers, geostationary satellites have carried instruments passively measuring radiation at infrared wavelengths or shorter. The shortfall of using infrared instruments in moisture studies lies in its inability to sense terrestrial radiation through clouds. Microwave emissions, on the other hand, are mostly unaffected by cloudy atmospheres. Land surface emissivity at microwave frequencies exhibit both high temporal and spatial variability thus confining moisture retrievals at microwave frequencies to over marine atmospheres (a near uniform cold background).

This study intercompares the total column integrated water content (precipitable water, PW) as derived from both the Special Sensor Microwave Imager (SSM/I) and the Geostationary Operational Environmental Satellite (GOES) VISSR Atmospheric Sounder (VAS) pathfinder data sets. PW is a bulk parameter often used to quantify moisture variability and is important to understanding the earth's hydrologic cycle and climate system. This research has been spawned in an effort to combine two different algorithms which together can lead to a more comprehensive quantification of global water vapor.

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The approach taken here is to intercompare two independant PW retrieval algorithms and to validate the resultant retrievals against an existing data set, namely the European Center for Medium range Weather Forecasts (ECMWF) model analysis data.

2. BACKGROUND

2.1 Physical Split-Window (PSW) Technique

The Physical Split-Window Technique was developed by Jedlovec (1987) and applied to GOES VAS data by Guillory et al. (1993). For the present application, split window channel brightness temperatures in the 11 and 12 μm region are used to simultaneously solve for PW and surface skin temperature. The scheme is derived from a perturbation form of the radiative transfer equation. In the retrieval process, PW is solved as a perturbation from an initial guess value. The physical approach requires this a priori information to include estimates of T(p), q(p), PW and T_s. From the temperature and mixing ratio profiles, channel transmittance and brightness temperatures are obtained and used in the solution equation. For a more detailed description of the PSW technique, please refer to Guillory et al. (1993). Previous applications of this technique have used a constant guess over land utilizing radiosonde data for the first guess profiles. Recently, modifications to the retrieval scheme have been made to allow for a varying guess using ECMWF or other analysis fields.

One of the main advantages of the PSW technique over other infrared moisture retrieval algorithms with VAS data is its independence from using dwell sounding (DS) data which is only available every 3 hours over a limited region. PSW utilizes VAS multispectral (MSI) full-disk data available hourly at 8 km resolution. The drawback is the increased small

detector single sample noise error associated with the MSI data. This error is reduced by spatially averaging the observed brightness temperatures over a local area. The remaining random error produces less than a 2mm error in PW retrievals (Guillory et al., 1993). GOES VAS pathfinder data for this study was obtained from the Space Science and Engineering Center at the University of Wisconsin for the month of August 1988.

2.2 Wentz SSM/I precipitable water algorithm

SSM/I geophysical tapes are obtained from the Marshall Space Flight Center (MSFC) Distributed Active Archive Center (DAAC). The algorithm solving for wind speed and atmospheric water vapor developed by Wentz (1992) was used to create the data set used in this study. The retrieval process is physically based and derives PW from brightness temperatures measured at the 22V, 37V, and 37H GHz frequencies. The model equations solve for transmittance at 22V GHz by utilizing sea-surface temperature climatology. A more detailed description of the retrieval process is given by Wentz (1992) and Liu et al. (1992). SSM/I PW are given at 0.25° spatial resolution over marine atmospheres. Due to significant scattering by hydrometeors, SSM/I PW is not available for rain rates in excess of 1.5mm/hr.

3. METHODOLOGY

Three case study days from August 1988 (during the benchmark period of the EOS Pathfinder project) were chosen for a region covering the Gulf of Mexico and Western Atlantic Ocean. These days (i.e. 10, 25, and 27 August) were subjectively chosen based on the amount of clear conditions in the SSM/I scan area so as to maximize the number of coincident cloud-free VAS retrievals. The human eye is still the most accurate means for cloud clearing. Therefore, VAS retrievals were carried out manually at 1500Z (at which time the entire domain is well illuminated in the corresponding visible imagery). ECMWF model analysis fields at 5° X 5° spatial resolution at 0000Z before and after the retrieval time were used as input for first-guess calculations. The performance of retrievals is weakened when using a 1200Z first guess profile (Jedlovec and Carlson, 1994). Coincident (within 0.1° latitude and longitude) SSM/I PW cells are then compared against the VAS retrievals.

4. RESULTS

Approximately 500 clear retrievals were made for the three case study days. For each case study day, the Bermuda High was quasi-stationary between 30-40N east of 70W. On 25 August, a cold front extended along the eastern and gulf coasts of the U.S. By 27 August 1200Z, a low had developed over New Jersey with a trough extending along the southeast U.S. coast. Table 1 presents the statistics of VAS versus SSM/I retrievals. Note the slightly higher mean PW for the VAS retrievals. The RMS difference represents about 14% of the mean PW values. A correlation coefficient of 0.7606 is quite good when considering the two completely independant sources of data (e.g. differing instantaneous field of views, spectral characteristics, and differing retrieval times).

Table 1: VAS PSW vs. SSM/I PW results from all 3 case study days. All units are in mm except for correlation (CORR).

	SSM/I	VAS
MEAN	42.5	44.6
STDV	6.77	9.23
RMS DIFF.	6.36	
MN DIFF.	2.13	
CORR.	0.7606	

Figure 1 displays the distribution of SSM/I and VAS retrievals. The frequency distribution of VAS retrievals are negatively skewed with the greatest number of retrievals near the 50mm PW bin. More moist VAS retrievals are observed when PW is greater than 50mm. Similarly, more dry VAS retrievals are found when PW is less than 32.5mm. SSM/I retrievals are more normally distributed with a slight negative skewness thus indicating few very moist retrievals.

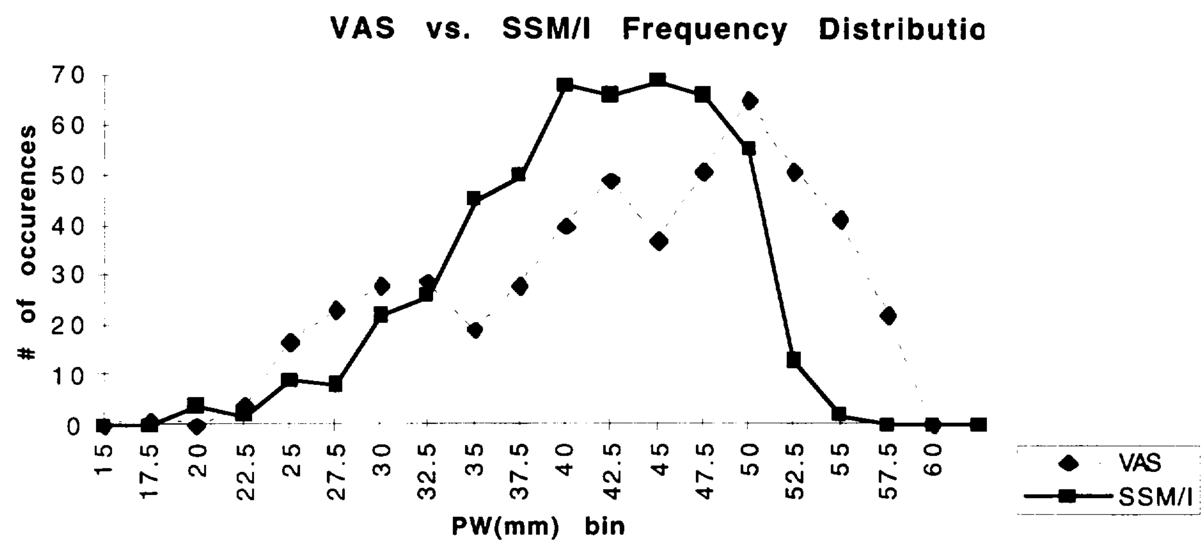

Fig. 1: SSM/I vs. VAS frequency distribution

The secondary "dry" peak in the VAS retrievals centered near 30mm contained points predominantly in the region of the Bermuda High (i.e. 25-40N, 60-75W) in the Western Atlantic Ocean.

More scatter is apparent for drier retrievals while less scatter and a moist bias in VAS retrievals becomes evident for PW greater than 40mm (Figure 2). Outlier retrieval points were isolated and identified. We found that the combination of dry SSM/I and moist VAS retrievals were common in regions of small low cumulus clouds with infrared brightness temperatures close to the sea-surface temperature. Manual cloud-clearing using the visible channel might not be an appropiate method for removing small low cumulus clouds from the retrieval process since pixel sized clouds might effect the split-window channel brightness temperatures even though the corresponding visible imagery might render low brightness counts (clear pixels).

These preliminary results show no distinct or outstanding features associated with the combination of very moist SSM/I and dry VAS retrievals. However, in one instance, a dry-air mesoscale convective outflow region near 40N 65W on 27 August was detected by the VAS retrieval (29mm) while the SSM/I PW retrieval showed little moisture variability associated with this feature (coincident retrieval of 48mm).

Over the study domain, VAS and SSM/I PW retrievals are validated against near coincident ECMWF model analysis PW grid points (i.e. within 0.1 degree lat/lon and +/- 3 hours). Mean PW for ECMWF, SSM/I , and VAS are 38.6, 43.8, and 47.7 mm respectively. Once again, the higher mean VAS PW might be an artifact due to low cumulus contamination as explained above. Interestingly, VAS and SSM/I moisture retrievals correlate better (r=0.79) against one another than against ECMWF (r~0.60). Further investigation with a larger working data set is necessary before a better "ground-truth" validation can be made.

5. CONCLUSION

The Physical Split Window (PSW) technique applied to GOES VAS data is compared against Wentz SSM/I precipitable water (PW) for cloud-free retrievals on three case study days in August 1988. VAS retrievals are observed to be slightly more moist on average. The correlation coefficient of the two independant data sets is 0.7606 with more variability (STDV=9.23mm) associated with the VAS retrievals which is possibly due to low cumulus cloud contamination in the "hand picked" PSW retrievals. More scatter between the two data sets is observed in drier regions. SSM/I retrievals offer the benefit of quantifying moisture in cloudy regions, but smaller scale features might not be resolvable as with the infrared technique. Preliminary results show the retrieval schemes correlate better against one another (r=0-.79) than against ECMWF PW (r=0.60). Overall, the two retrieval techniques show excellent potential in complementing one another.. More recent results for the entire month of August will be presented at conference time.

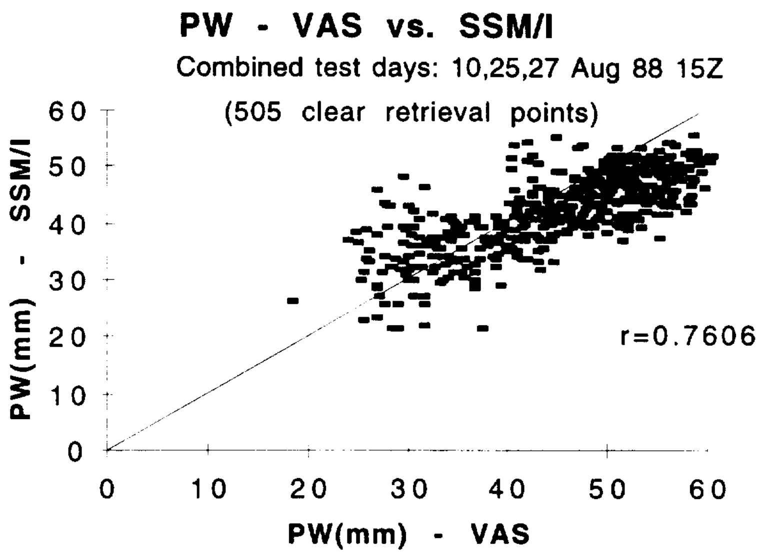

Fig. 2: Scatter plot of SSM/I vs. VAS retrievals.

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